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ABSTRACT

The utility of multiple discriminant function analysis (MDFA) to differentiate among the interest patterns of engineers was examined. Subjects were 229 engineers who were administered the Strong Vocational Interest Blank (SVIB) in 1935 as college freshmen (1935 FR) and again in 1966, and 210 freshmen who completed the SVIB in 1966 and had persisted in an engineering curriculum for two years (1966 FR). Two MDFA analyses were conducted and cross-validated. Statistically significant profile differences were found. 1935 FR preferred occupations which involved the technical application of knowledge. In 1966, their preferences included managerial endeavors. 1966 FR responses were congruent with those of men in occupations requiring sophisticated quantitative and research skills. They exhibited more interest in management and business than did their predecessors as freshmen. These findings provided a basis for career counseling inferences with prospective engineers and attested to the value of MDFA for research of this type. (Author)

DISCRIMINANT FUNCTION ANALYSIS OF INVENTORIED INTERESTS AMONG SELECTED ENGINEERING GROUPS

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The utility of multiple discriminant function analysis (MDFA) to differentiate among the interest patterns of engineers was examined. Subjects were 229 engineers who were administered the Strong Vocational Interest Blank (SVIB) in 1935 as college freshmen (1935 FR) and again in 1966, and 210 freshmen who completed the SVIB in 1966 and had persisted in an engineering curriculum for two years (1966 FR). Two MDFA analyses were conducted and cross-validated. Statistically significant profile differences were found. 1935 FR preferred occupations which involved the technical application of knowledge. In 1966, their preferences included managerial endeavors. 1966 FR responses were congruent with those of men in occupations requiring sophisticated quantitative and research skills. They exhibited more interest in management and business than did their predecessors as freshmen. These findings provided a basis for career counseling inferences with prospective engineers and attested to the value of MDFA for research of this type.

Engineers, both as students and as practitioners, have been a popular group for study by many researchers of inventoried interests. The Strong Vocational Interest Blank for Men (SVIB) has been employed as the interest assessment tool in many of these efforts. The following are representative of the diversity of this research: (1) initial establishment of the Engineering Scale on the SVIB (Strong, 1929); (2) examination of longitudinal data to determine if interests are consistent over time (Strong, 1952; Apostal, 1966; Benjamin, 1967); (3) differentiation of interests among students in various engineering curricula (Mayfield, 1960; Apostal, 1968); (4) use of the SVIB as a predictor of academic or vocational satisfaction and success (Benjamin, 1967; CoBabe, 1967); (5) differentiation of interests among occupational subgroups (Strong, 1929; McCampbell, 1966); and (6) differentiation of engineers from other occupational groups (Chappell, 1967).

The purpose of this study was to investigate the utility of multiple discriminant function analysis (MDFA) in discerning the differences in inventoried interests among selected engineering samples. Specifically, the investigators sought to determine (1) if the SVIB interest patterns of persons entering engineering 30 years ago had changed, (2) how similar the inventoried interests of current engineering students were to the interests of engineers now established in their careers and (3) what measurable differences in interests could be found among engineers ordered by curricula.

METHOD

t-score data for each of the 56 occupational scales scored for the revised edition of the SVIB (Campbell, 1966), plus six special scales, were determined for a group of 229 male engineers who were administered the instrument as freshmen at Purdue University in 1935 (1935 FR) and retested in 1966 (1966 RT). At the time of retest, these men were in their fifties and considered to be at the peak of their careers. In addition, 210 male Purdue University engineering students who completed the SVIB as freshmen (1966 FR) and had persisted in an engineering curriculum for two years at the time of this study provided similar data. This latter group was thought to be representative of those who graduate eventually from the Schools of Engineering (Martin, 1956).

Two multiple discriminant function analyses (Cooley and Lohnes, 1962) were completed. For the first analysis, the criterion samples were treated as though they constituted three different groups of engineers. Each group was divided randomly to provide a hold-out sample for cross-validation purposes. For the second analysis, each subject group was ordered further into one of five engineering specialty sub-groups providing 15 criterion groups for study. No cross-validation sample was established for the second analysis. The sub-groups N's are shown in Table 1.

Table 1 here

MDFA may be compared to multiple regression analysis in that a vector of multivariate weights is derived which maximizes a given prediction. However, in the instance of multiple regression analysis, a univariate criterion usually is predicted for a sample drawn from a single population. With MDFA, a multivariate prediction is made with respect to which of two or more populations an individual is most similar. The use of every difference is formalized so that classifications are as certain as possible (Mangnusson, 1967). Furthermore, no assumption is made about the form of regression, nor is any assumption made about the correlations between predictors and criteria.

Multiple discriminant function analysis was developed by Fisher (1936) for two-group discrimination problems and later it was modified by him to accommodate more than two groups (1938). Tiedeman, Rulon and Bryan (1951) were among those who used MDFA early, but it has been less than ten years that researchers, other than Tiedeman and his students, have used this technique. The success demonstrated by the Scientific Career Study (Cooley, 1958 and 1963) and the Harvard Studies in Career Development (Cass and Tiedeman, 1960; Dunn, 1959) and advances in computer technology have stimulated increased use of MDFA. Recently, Chappell (1967) and CoBabe (1967) reported favorable MDFA results. Both men concluded that this procedure is a powerful tool for discriminating among groups which, heretofore, largely have resisted sharp self-report measure discriminations.

For both analyses, where appropriate, the DISCRIM, RSPACE and CLASSIF computer programs (Cooley and Lohnes, 1962) were employed. Because the dimensions of these programs limited the number of variates that could be analyzed at any one time to 50, preliminary analyses were necessary to reduce the 62 variates available to 50 or less. The criteria for variate deletion were scaled coefficients that were at or near zero for each of the discriminant functions extracted.

As a part of the DISCRIM phase of the analysis, the product of the inverse of the within-group variance-covariance matrix (W^{-1}) and the between group variance-covariance matrix (A) was computed to yield latent roots. Associated with each latent root was a single vector of discriminant function coefficients, equal to the number of variates analyzed. The vector of coefficients associated with the first root is termed the first discriminant function. Similarly, the vector of coefficients associated with the second latent root is called the second discriminant function. It is possible to extract a number of latent roots which is equal to, or fewer than, one less than the number of populations or the number of predictor variates used, whichever is the lower number.

The statistical significance of the latent roots was tested by the Chi-square approximation described by Rao (1952). In analyses where more than one root is extracted, a preliminary test of the generalized discrimination power of the several roots is performed through the use of Wilks' lambda criterion (1932). The null hypothesis tested by this criterion is that the central tendency estimates for the population samples are the same value and that the variance among these samples equals zero. The estimates computed for discriminant coefficients maximize the non-overlap of respective criterion group distributions. The distribution of the lambda statistic may be transformed to estimate the F distribution (Cooley and Lohnes, 1962). Completion of discriminant function analysis is justified for only those roots shown to have significant discriminant power. Each significant discriminant function was scaled to permit a subjective comparison of the relative importance of the contribution of each variate to discriminant power. This was accomplished by multiplying the coefficient which had been computed for each variate by the square root of the corresponding elements of the main diagonal of the within-group variance-covariance matrix.

Discriminant scores for each subject were calculated by multiplying each discriminant function vector coefficient by a subject's vector of SVIB t-scores. During the RSPACE phase, centroids were determined to estimate the central tendnecy of the distribution of a given discriminant score for a given criterion group. By definition, given pairs of discriminant function dimensions form the orthogonal axes of a bivariate space within which relevant centroid coordinates of each criterion group may be plotted. The criterion sample variances associated with the variates analyzed also were pooled to estimate the discriminant score variances associated with each centroid. The standard deviations related to these variances (centours) may be used in conjunction with the centroids to represent graphically the density of the sample scores surrounding a centroid.

Finally, the discriminant scores of each subject in the cross-validation samples (available only for the first analysis) were derived through the utilization of the CLASSIF phase of the computer program. Cooley and Lohnes (1962) provide a method of computing Chi-Square values to test the probability of each subject's array of discriminant scores falling in each criterion population domain. By this means subject group assignments were executed. A contingency table of group assignment successes and failures was derived and also tested by the Chi-Square statistic. The extent to which cross-validation subjects can be assigned correctly to their known criterion groups using functions determined from initial sample data constitutes a criterion to evaluate the validity of a given discriminant function analysis. The .01 level of significance was held critical for all analyses made.

RESULTS

Three-Group Analysis

Based upon data from the 40 SVIB variates shown by preliminary analysis to exhibit the most discriminant power for the first and second latent roots derived (v-I and v-II), the DISCRIM analysis yielded a significant lambda value. The results of Rao Chi-Square approximation are presented in Table 2. The percent of discrimination attributed to each latent root also is shown.

Table 2 here

In table 3, the criterion sample centroids and centours for each discriminant function are reported.

Table 3 here

In Figure 1 a graphic representation of these latter data is depicted. Because of the negative values of the group centroids for v-I, all plots occurred in the fourth quadrant of the relevant bivariate space.

Figure 1 here

The dispersion of within-group discriminant scores was represented by two elipsoids displayed about each group's centroid bivariate coordinate plot. The arch of each elipsoid passed through four points, one drawn one standard deviation in distance from the bivariate centroid plot (68th centour) and the other two standard deviations from this point (95th centour). The 68th centour is thought to encompass the discriminant function score plots for approximately 68 percent of the subjects in a given group, while the 95th centour should account for about 95 percent of these plots. Each group occupied a distinct graphic field. There was no over-lapping of the 68th centours and only minimal 95th centour dispersion contact.

The discriminant functions, centroids and dispersions determined from initial criterion sample data were utilized to make predictions regarding group membership for each criterion group cross-validation sample (1935 FR, N = 114; 1966 RT, N = 115; and 1966 FR, N = 105). The results of the successful cross-validation CLASSIF analysis are included in Table 4.

Table 4 here

When ranked for magnitude, scaled coefficients were indicative of each variate's contribution to the discrimination among criterion groups. All groups appeared to be differentiated by the first discriminant function while the second function seemed to differentiate only the 1966 FR from others (Clemens, 1969). The 1935 FR responded similarly to men in occupations which involve the technical application of knowledge and the classification of objects. In 1966 the responses of these men were congruent with those of men in occupations which require technical, applied and managerial skills. In contrast, the 1966 FR responded like men who prefer occupations that require sophisticated quantitative and research skills. Moreover, as freshmen, the 1966 FR group appeared to be more interested in management and business activities than were their 1935 counterparts.

15 Group Analysis

Data from the 50 SVIB variates shown by preliminary analysis to possess the most discriminating power for v-I, v-II and v-III provided a significant lambda value. Table 5 gives the results of the Rao (1952) Chi-Square approximation test of the first six latent roots and the percent of trace attributed to each root.

Table 5 here

To facilitate interpretation, the centroids and centours for each of the 15 groups for v-I and v-II only are reported in Table 6. This was thought justified on the basis of the proportion of the total percent of discrimination which these two functions exhibited.

Table 6 here

The similarities between the configurations of the three-group data (see Figure 1) and the 15-group findings are graphically portrayed in Figure 2. This graphic array was constructed by superimposing the 2nd quadrant upon the 4th quadrant. The signs nearest to the ordinates belong to the 4th quadrant. By placing an imaginary line across the top of the figure and another to the left, one can visualize again the 15-group centroid clusters in the 2nd quadrant.

Not only did engineering specialty subgroup centroids cluster near their respective three-group centroids, but specialty centroids also assumed similar pattern positions (*e.g.*, the "A" centroid is positioned to the left of the other four centroids in all three instances).

Figure 2 here

Discriminant functions *v*-I through *v*-V did not separate subjects effectively. Ordering subjects into one of 15 subgroups apparently resulted in a loss of discrimination power that made proper classification improbable. Even though the related *F* statistically was significant, an inspection 15-group suggested that the discrimination accomplished was "between three-group" discrimination rather than "between specialty subgroup" discrimination.

DISCUSSION AND CONCLUSIONS

Over the 31-year interim, between SVIB test and retest, the 1935 FR shifted in their interests from an applied-quantitative orientation to what might be termed "technical management." The 1966 FR were found to be somewhere "in between and above" the 1935 FR and the 1966 RT in interest preferences. They seemed to be more interested in scientific and managerial pursuits at present than were their 1935 counterparts and less oriented toward occupational endeavors requiring the application of quantitative skills. With this combination of interests and concomitant abilities, they would seem to be oriented toward work as a business consultant, an electronics excecutive, a space engineer or project manager, to cite but a few possible career choices.

Presumably, these findings possess utility for counseling with beginning engineering students. Though it would not be appropriate to stereotype students according to SVIB profiles (*e.g.*, a "1935 FR type"), this study yielded results that support a contention held by some counselors for some time: there is justification for making certain subjective inferences from the examination of overall SVIB profile variations. These inferences are thought to be the product of a "clinical acuity" which accures from extensive experience involving the interpretation of interest test data.

Prospective engineering students who respond to the SVIB items in a manner similar to the 1935 FR group might be alerted to consider an engineering technology curriculum rather than a regular engineering specialty at a university which requires higher level mathematics and science training. Technology degree programs generally are terminal in nature and prepare persons to engage in the technical application of knowledge. Those students who seem to prefer occupations which require applied, technical and some management skills might be encouraged to examine curricular offerings where both technical and management courses are offered at the undergraduate level. Majors in areas such as industrial management or engineering technology would appear to be viable choices for those who respond to the SVIB similarly to 1966 RT's. In contrast, students whose responses are congruent with 1966 FR probably should be encouraged to remain in a regular four- or five-year engineering curriculum, assuming they possess the necessary educational background and academic abilities. Also, it might suggest that these persons give serious consideration to graduate study that would provide preparation for management positions, research direction and business pursuits.

The use of MDFA in this study led to findings that seem highly meaningful and not easily attainable through other statistical treatments. It was concluded that this technique is an effective statistical procedure for discriminating among occupational groups where data of the sort analyzed are available.

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Table 1

Subgroups for Statistical Analyses

	1935 FR	1966 FR
Electrical	39	49
Engr. Science	15	13
Mechanical	106	100
Civil	30	24
Chemical	39	24
	229	210

Table 2

Approximate Chi-Square Values for Latent Roots of SVIB Variates from Three-Group Analysis

Root	df	Approximate Chi Square Value	Percentage of Discrimination
1	41	384.21**	68.07
2	39	283.81**	31.93

** Significant beyond the .001 level.

Table 3

Centroids and Standard Deviation Values for v-I and v-II from Three-Group Analysis

Criterion Group	v-I		v-II	
	Centroids	Standard Deviation	Centroids	Standard Deviation
1935 FR Engineers	-21.08	3.96	4.95	4.92
1966 RT Engineers	- 3.77	4.52	4.22	5.24
1966 FR Engineers	-11.66	4.76	17.03	5.45

Table 4

Frequencies of Successes and Failures in Classification of Three-Group Analysis Cross-Validation Groups on v-I and v-II

Membership Predicted	Membership Actual 1935 FR Freq.	1966 RT Freq.	1966 FR Freq.	Totals Freq.	Chi Cq.
1935 FR Engrs	92	7	13	112	115.47
1966 RT Engrs	9	93	14	116	108.81
1966 FR Engrs	13	15	78	106	87.70
Totals	114	115	105	334	311.98**

**Chi Square of 18.46 (4 df) significant at .001 level.

Table 5

Approximate Chi-Square Values for Latent Roots of SVIB

15-Group Analysis

Root	df	Approximate Chi Square Value	Percent of Discrimination
1	63	721.04**	44.23
2	61	548.37**	28.65
3	59	181.24**	6.93
4	57	110.58**	3.94
5	55	99.77**	3.50
6	53	72.00	2.50

** Significant beyond the .01 level.

Table 6

Centroids and Standard Deviation Values for v-I and v-II
from 15-Group Analysis

Criterion Group	Centroids	Standard Deviation	Centroids	Standard Deviation
1935 FR Engrs				
Electrical	11.09	4.15	-16.95	4.98
Engr. Science	13.03	4.28	-19.76	3.95
Mechanical	11.87	5.02	-20.56	4.88
Civil	13.46	6.10	-21.49	5.42
Chemical	14.71	6.16	-21.03	5.72
1966 RT Engrs				
Electrical	29.52	6.95	-15.39	5.67
Engr. Science	35.64	6.13	-19.96	5.67
Mechanical	32.88	6.27	-18.67	5.46
Civil	32.66	8.06	-18.41	8.75
Chemical	34.61	8.15	-19.32	11.77
1966 FR Engrs				
Electrical	18.87	9.39	- 5.49	11.22
Engr. Science	24.46	6.53	- 4.79	8.60
Mechanical	19.40	8.81	- 6.57	7.87
Civil	24.05	4.35	- 6.97	7.45
Chemical	21.96	7.27	- 5.99	5.70

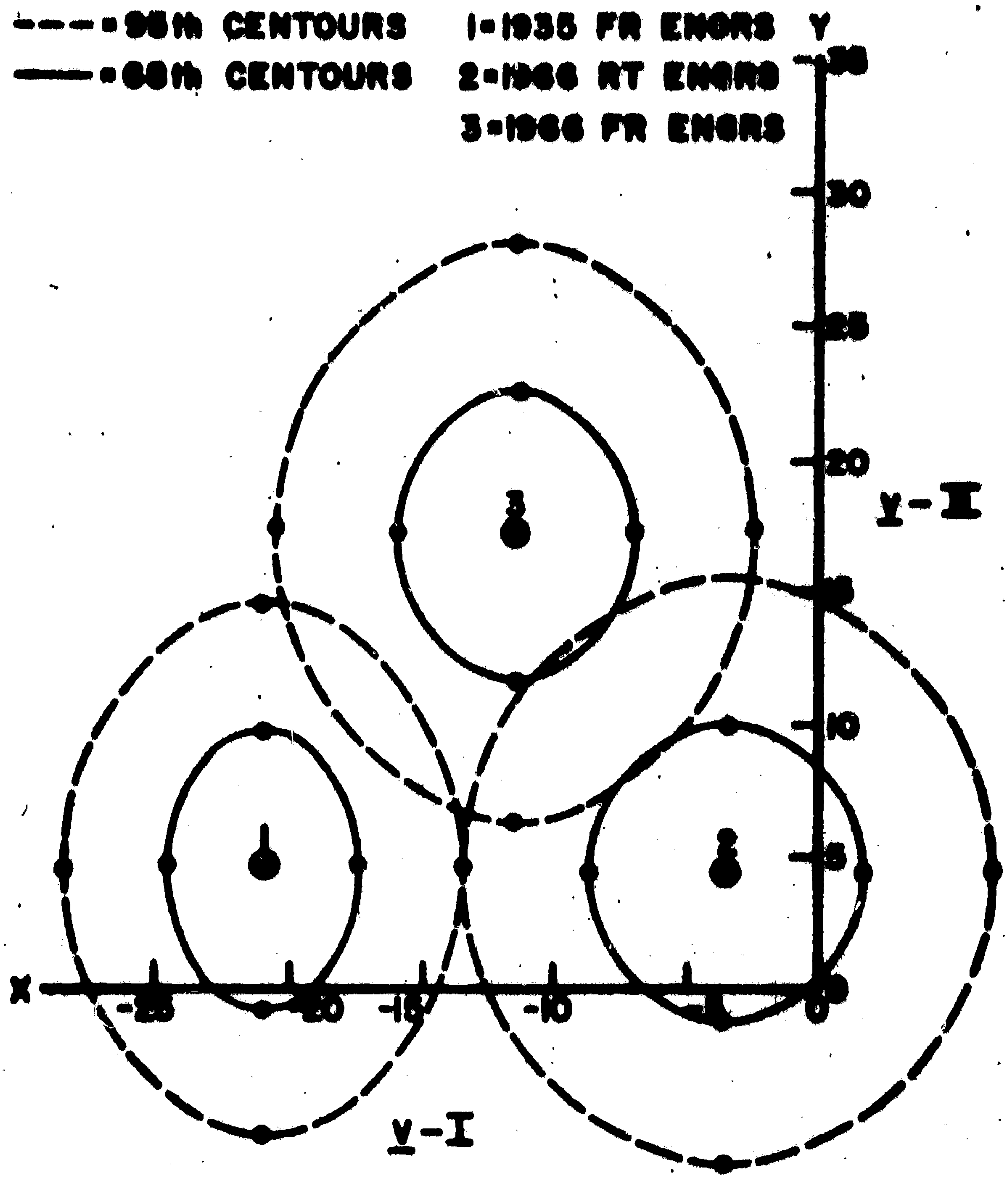

FIGURE 1 THREE CRITERION SAMPLE CENTROIDS AND 68th AND 95th CENTOURS FOR 40 SVIB VARIATES

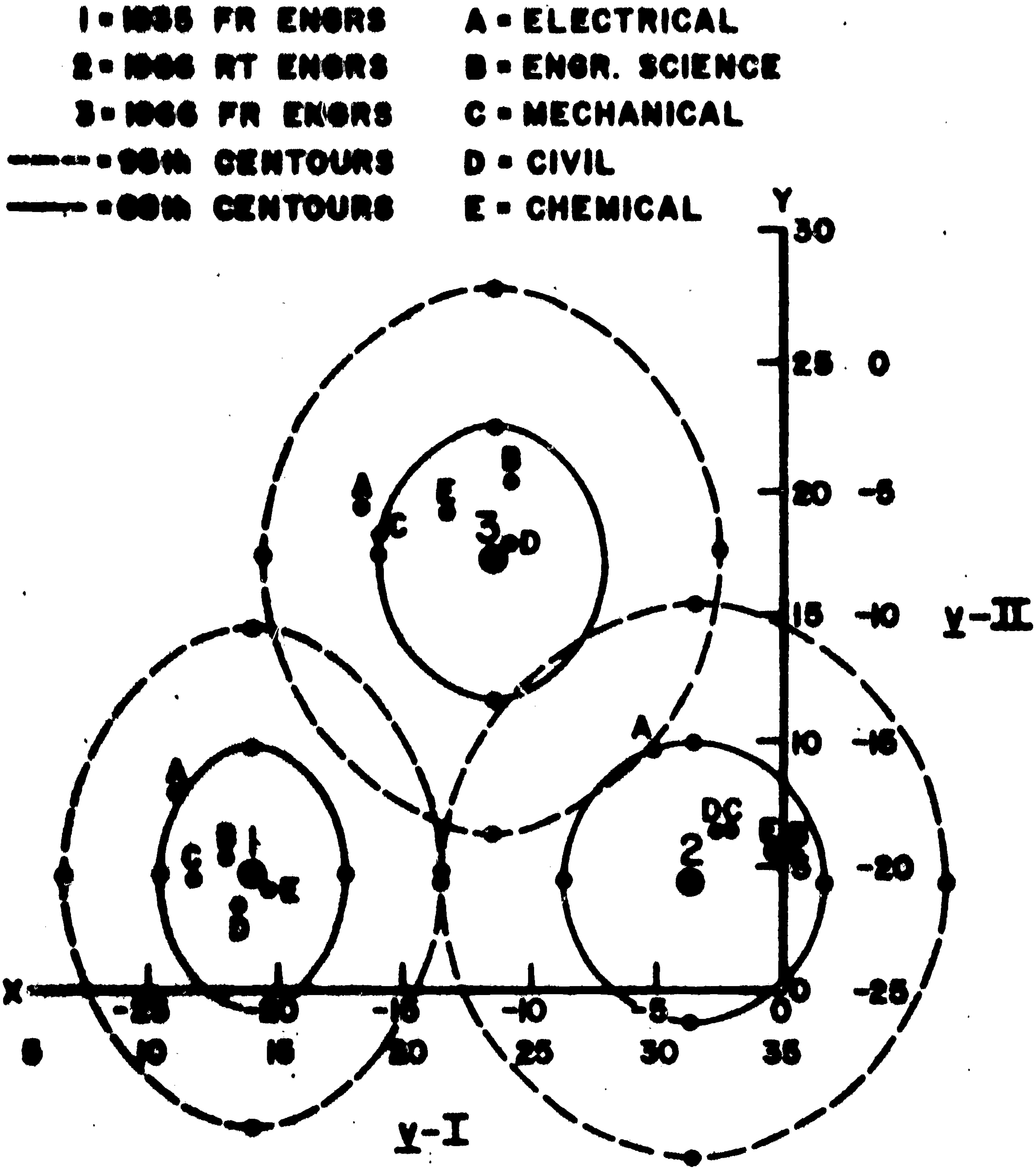

FIGURE 2 THREE CRITERION SAMPLE CENTROIDS AND 68th AND 95th CENTOURS WITH 15 GROUP CENTROID CLUSTERS PLOTTED IN A CONVERTED GRAPHIC FIELD

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